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OBSERVATIONS ON SOME VINE DISEASES IN SONOMA COUNTY, CALIFORNIA.

By O. BUTLER.

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OBSERVATIONS ON SOME VINE DISEASES IN SONOMA COUNTY, CALIFORNIA.

By O. BUTLER.

Introduction.—In 1903 the Viticultural Department of the College of Agriculture of the University of California took up the study of a disease that, for a few seasons, had been observed in Sonoma County and was beginning to cause some anxiety among the vineyardists. After an inspection of the vineyards of Sonoma County from Santa Rosa to Cloverdale, including those of Alexander Valley and Dry Creek, we found that the "Red-leaf disease," as the malady was called, was sufficiently widespread to require special attention. The "Red-leaf disease" was, at that time, associated by many persons with the Anaheim disease, and by some with Anthracnose. The first theory was set aside *à priori*, on account of the difference in the effect on the canes and grapes, and also on account of the lack of virulence of the disease when attacking the Mission vines.* The suggestion that it might be Anthracnose was easily set aside, as the markings of the disease on leaves, canes, and berries are of an entirely different character; it is very doubtful that the true Anthracnose† has ever been found in a vineyard of California.

On my return from this trip of investigation, I passed through Napa Valley to compare the "Red-leaf disease" with a malady of similar character that had caused damage in some sections, and, after a consultation with Dr. E. W. Hilgard, it was decided to start a methodic study of the "Red-leaf disease," and Mr. O. Butler was appointed to carry out the investigations. This bulletin gives the results of his preliminary observations.

During the same season arrangements were made with several vineyardists to establish experiment plots on their land during the following year.

While investigating the "Red-leaf disease," Mr. Butler found that a number of maladies, either parasitic or physiological, were responsible in a measure for the weakness or dying of the vines. Among these affections Phylloxera, Root-rot, Mildew, lack of affinity between scion and stock, lack of adaptation of stock to soil, mechanical injuries, Erinose, and Black-knot are quite prevalent in Sonoma County, as well as in most vineyard districts of California.

A description of some of these will be given in separate bulletins, while others have been already discussed in former publications: Report of Viticultural Commission, 1893; Bulletins Nos. 127, 131, 146, 148, of the Agricultural Experiment Station of the University of California.‡

Mr. Butler's observations seem to show that the cause of the Red-leaf disease is not parasitic, but that it is more probably due to soil and atmospheric conditions. These observations will be kept up during the coming season, and a careful examination of the subsoil and moisture-contents of the experimental plots will be made through the growing season, so that definite conclusions may be drawn.

E. H. TWIGHT.

THE RED-LEAF DISEASE.

In 1903, the attention of the public was aroused by the alarming notices published in the Sonoma County papers about a new and mysterious malady, which was unanimously denominated Red-leaf disease. Opinions were freely aired as to the nature of the disease, but the

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* N. B. Pierce, Bulletin No. 2, Div. Veg. Path., U. S. Dept. Agr., page 7.
† Sphaceloma ampelinum.
‡ Also, in "American Vines," by P. Viala and Ravaz; translated from the French by R. Dubois and E. H. Twight.

disease itself was not described. The reader was left to conjecture, from the name the grape-growers were agreed upon giving to it, that a red leaf was its main characteristic. Beyond this, however, the grape-growers did not entirely agree; the term red leaf is indefinite enough to allow of a wide individualistic interpretation, and the grower who had vines suffering, or dying, from a cause undiscoverable to him, and showing a foliage tinted, perchance, here and there with red, was inclined to call the trouble from which his vines were suffering the Red-leaf disease. This diversity of opinion was at first rather confusing, and was more a hindrance than a help in furthering the investigations. In fact, of the three vineyards kept constantly under observation, only one was finally found to be free from any other disease than the Red-leaf; and the development and characteristics of the said disease in this vineyard were a great help in diagnosing the malady in other parts of the county, and under less favorable circumstances.

The result of our investigations of the disease under consideration may be conveniently divided into two parts: (1) Description of the Red-leaf disease and its relationships; and (2) Results of the winter and summer spraying experiments instituted to combat it.

DESCRIPTION OF THE DISEASE AND ITS RELATIONSHIPS.

The Red-leaf disease may affect the shoots, the leaves, the peduncles, the pedicel, and the fruit of the vine; it may affect the uppermost part of a cane, or several canes; one entire side of a vine, or, but more rarely, an entire vine. One vine may show all the characteristics of this disease, and another only a part, or perhaps, only one of them. The disease may never proceed beyond the first stages, a not uncommon feature, or it may develop slowly until all its characters are patent to the most casual observer; more often, however, its development is rapid, and it would be somewhat difficult to distinguish the first stage, which is rather obscure, from those final stages which characterize it particularly.

Allowing, then, for the irregularities in the development of the Red-leaf disease, and for the absence of anything like progression from one stage to another, the reader will find in the following description the means of identifying this disease, without much difficulty, whenever it occurs in his vineyard.

Effect of the Disease on the Leaves.—The leaves near the apex of the shoots, including those recently expanded, and perhaps for a foot or two down, become pale, especially in the interveinar spaces. If a leaf in this stage is picked and observed by transmitted light, and with the underside facing the eye, all the fine network of veins will be found to be discolored. This discoloration of the small veins appears simultaneously with the loss of color in the leaves; in the recently expanded

leaves, which are naturally yellowish-green, this discoloration is more indicative of the disease than the change in color. Following the loss of color, the leaves become somewhat convex and the edges curl toward the lower surface; they lose their natural appearance; the tissue between the main veins sinks, and the veins themselves stand out like ribs. In mild cases the disease may develop no further than this. The affected leaves, however, fall off sooner or later, and generally with their stalks (petioles).

In severe cases of the disease, the recently expanded leaves may dry up suddenly and totally without malformation of any kind; or, as occurs more frequently, the parenchyma becomes pale yellowish-green, and the inclosed network of small veins discolored; then, usually, the lobe, or at least the upper portion of it, or in entire leaves that portion of the parenchyma which occupies the equivalent position, including one wing of the petiolary sinus, becomes more or less convex and the tissue sunken between the veins, which stand out, often in bold relief.

At this stage the tissues begin to dry rapidly from the periphery toward the petiole, at the same time retaining their peculiarity of form. When dry, the tissues are brittle and reddish brown. As soon as the discoloration has reached the petiole, the entire leaf and leaf-stalk may fall together. In older leaves, those not yet fully developed and still growing, one observes great variations—variations which can not be accounted for by the position of the leaf in relation to other diseased leaves, or by its age. Some leaves show the characteristics just described as typical of recently expanded ones, except that they do not fall prior to the dying of the convex and furrowed area. The drying of that portion of the leaf proceeds as rapidly in one case as in the other. In the more fully developed leaves, however, the action is sufficiently striking. At the petiole, and in the region immediately adjoining it, the mid-rib serves as a line of demarkation between the living and the dead tissues. The dead tissue soon separates from the petiole, which, in turn, discolors. At this stage the leaf-blade separates from the petiole, which, though drying up and discoloring more or less from the apex down, remains a while longer attached to the shoot. In other cases, besides the dead and furrowed area, there may appear between the veins, on other parts of the leaf, spots which, at first yellowish, become, at the same time as the aforementioned area, dry and reddish-brown in color, except for a narrow margin next to the still green or greenish-yellow tissue. Or again, the leaves may present the following appearance: The leaf-tissue, while still green, becomes sunken between the veins; then, in one or sometimes both corners, the leaf becomes pale greenish-yellow and between the veins, in the remainder of the leaf, appear spots of various sizes of the same color. These spots enlarge and even run together to form stripes. At this stage the discolored areas begin to dry rapidly, assuming the familiar reddish-brown color. The tissues next the petiolary sinus rapidly dry up from the periphery inwards, but do not encroach upon the mid-rib, and one may sometimes find a leaf which still adheres to its stalk, after the parenchyma on each side has become detached. A slight margin of yellowish-green sometimes separates the dead furrowed area from the still living tissues; this margin of yellow is, however, generally more distinct around the spots and stripes of dead tissue in the other parts of the parenchyma. The leaves fall from the petioles, which soon follow them.

In fully-developed leaves and old leaves, the disease is not accompanied by any distortion or furrowing of the leaf-blade. It affects only the tissues between the main veins, and first appears as suffused greenish-yellow spots, which, at first indefinite, become gradually larger and more definite in outline, and often merge together, forming large macu-

lations and stripes, which are more or less yellow—the intensity of the colorations depending, it would seem, on the rapidity with which the disease has progressed. The center of the spot now dies, becoming reddish-brown, sometimes almost with a brick tint and a sub-glossy appearance when death has been rapid. According to the rapidity of death these spots or stripes are surrounded, either (*a*) with a thin border of dull, deep red, which, in turn, is separated by a suffused yellow or greenish-yellow band from the green of the still healthy surrounding tissues; or (*b*) with a border of yellow, either suffused and broad, or thin and with a more definite margin; or (*c*) directly by the healthy green tissue itself. Sometimes the old leaves near the base of the shoots show a slight variation from the characteristics just described. These leaves, as soon as the disease begins to appear between the veins and the spots enlarge and merge to form stripes, become more or less greenish-yellow in the entire parenchyma. The dead areas, instead of being reddish-brown and in sharp contrast to the living tissues, are fawn-colored and soft, crumbly, tear easily, and fall away. The affected leaves thus become deeply incised, sometimes almost to the petiole, from which they hang in two, three or more pieces.

In the case just described, as likewise in the preceding, the leaves may remain attached to the shoots for an indefinite time, and when they fall it may be either with the petioles, or before them.

Effect of the Disease on the Fruit.—The fruit of white varieties of grapes appears to be more sensitive to the Red-leaf disease than that of black varieties. It would seem that the latter show the characteristics of this disease more markedly on the foliage, except in severe cases, and toward autumn, whereas in the former the disease is more conspicuous on the berries.

The Red-leaf disease may affect the fruit soon after setting. When this occurs, on passing the hand over a diseased bunch of grapes, the berries come off either with or without the pedicels. They even fall of themselves, and the stem (peduncle) dries up and falls also. This manifestation of the disease is more frequent among the red than the white grapes. The more noteworthy characters begin to show unmistakably on the berries when the clusters of grapes are a month or a month and a half old, and only become general just prior to the beginning of maturation. The berries become suffused with livid discolorations, which are sub-cuticular, the cuticle itself not being affected until later. The tissue of the berries in the center of these spots generally falls away from the epidermis, which then collapses. The livid and sunken spots thus formed may be more or less numerous, and large or small; they are more frequent on the exposed berries than on those in constant shade; they are more frequent on the sides of the berries exposed to the light than on the shady sides. When they do not fall off at this stage, the berries shrivel and dry up.

When the berries become affected just previous to maturity, or after maturity has begun, they ripen imperfectly and, as a rule, are never worth picking. The clusters of diseased grapes are generally allowed to remain on the vine, and, after defoliation, they may be observed hanging from the canes.

Effect of the Disease on the Shoots.—The shoots are not affected directly by the Red-leaf disease. The symptoms they show are a consequence, so to speak, of the intensity of the malady on the leaves. When the shoots are partially defoliated (counting from the apex), their growth is only checked for a while. When the defoliation is more severe, the apex curls somewhat, discolors and dies. Death, however, is not confined to the apex, but proceeds for a greater or less distance down the shoots, the discoloration progressing, as it were, by stages. The shoots shrink and gradually turn brown. The shrinkage of the tissues is most noticeable near the nodes, and, except in more lignified parts of the shoots, always precedes the discoloration. The discoloration of the shoots is somewhat irregular, and more rapid in the parts exposed to the sun. When defoliation is complete, the shoots sometimes die from apex to base. When they are not defoliated, their lignification does not seem to be materially interfered with, though it is often irregular. One may even find, in rare cases, green immature spots or stripes in the midst of lignified tissue, but even such an irregularity as this does not persist. The immature spots mature in time.

The Relationships of the Red-leaf Disease.—The Red-leaf disease appears more or less closely related to the Folletage, the Rougeot, and the California Vine disease. It resembles the Folletage by the sporadic suddenness with which it sometimes appears; the Rougeot, in its not being immediately fatal, and possibly also in some of its foliar colorations; and the California (Anaheim) vine disease in the striping of the leaves.

The cause of the Folletage and of the Rougeot has been thought to be due to the rupture of equilibrium between transpiration and absorption, but that of the California vine disease has not been determined. In the case of the Red-leaf disease, the evidence gathered in a single season seems to point to a physical rather than to a parasitic cause.

Resemblance between the Red-leaf Disease and the Folletage.—The Folletage affects the vines in midsummer. "One* sometimes observes, especially in July and August, vines in excellent health dying suddenly in a vineyard. The leaves wilt, fade, and dry; the shoots and even the arms succumb. The vines may die in a few minutes. * * * It is only isolated vines (they may sometimes be numerous) which are affected by this disease; * * * a whole vineyard is never affected. Entire shoots, or even whole arms, may be destroyed on a diseased vine

*P. Viala: "Les Maladies de la Vigne," page 471.

without the other arms or shoots being affected." Vines planted in "deep, cool, damp soils" are subject to this trouble, especially when heat follows heavy rains. In dry soils the Folletage also occurs. In both cases it is due to a rupture of the equilibrium between the transpiration of the leaves and the absorption of the roots. The resemblance between the effect of the Folletage and that of the Red-leaf disease is not a very close one. The Red-leaf disease is apparently not fatal in a single season, if ever. Like the Folletage, however, it affects the vines with greatest intensity and suddenness during July and August, and more frequently partially than wholly. The death, either total or partial, of the affected shoots does not follow the attack in the great majority of cases. In some cases of Folletage, the foliar characteristics are very similar to those of vines affected with the Red-leaf disease, if we may judge from plates 17, 18, and 19 given as illustrations of this disease in Bulletin No. 2 of the Division of Vegetable Pathology, U. S. Department of Agriculture.

Resemblance between the Rougeot and the Red-leaf Disease.—The Rougeot is considered by some authors as a mild form, so to speak, of the Folletage, and attributable to the same cause. The Rougeot affects vines as sporadically and irregularly as the Red-leaf disease. Its foliar characteristics remind one of those of the Anaheim, or the Red-leaf disease. Vines affected with Rougeot generally recover.

Resemblance between the Red-leaf and the California (or Anaheim) Vine Disease.—For a description of this disease the reader is referred to Pierce's memoir on the subject.* To describe the disease, even in the most summary manner, is not necessary in the present publication. The California vine disease and the Red-leaf disease are sufficiently different from each other, in their salient characteristics, to be easily distinguished without resorting to details. The reader will find, in the following comparison, a sufficient proof of the distinctiveness of these two diseases:

Anaheim Disease.†	*Red-leaf Disease.*
The disease is cumulative.	The disease is not cumulative.
The newly-formed leaf either remains green or is striped yellow or red, according as the grapes are white or red. (*loc. cit.*, page 142.)	The newly-formed leaves either dry with deformation (leaves just expanded) or are paler than normally and convex (leaves two or more nodes from the apex).
As a rule the leaves fall from the base of the canes first. (*loc. cit.*, page 45.)	The leaves fall from the apex first.
The roots are decayed. (*loc. cit.*, page 57, et suiv.)	The roots are healthy.
Grapes dry and remain on the vine, or fall off, but not very frequently. (*loc. cit.*, page 53.)	Grapes are mottled with livid, sunken spots.
A diseased vine shows the disease most generally on all its shoots. (*loc. cit.*, page 79.)	The number of shoots affected is variable, though rarely total.

*Bull. No. 2, Div. Veg. Path., U. S. Dept. Agr.
†N. B. Pierce: "California Vine Disease," loc. cit.

The above consideration of the relations of the Red-leaf disease leads one to conclude that the Red-leaf and the Rougeot are the more closely related. If this conclusion is proved to be correct, then the grower need not feel greatly alarmed even when a considerable percentage of his vines are affected with the Red-leaf disease.

RESULTS OF WINTER AND SUMMER SPRAYING EXPERIMENTS.

Toward the end of January, 1904, the active help of three growers, who were anxious to find a remedy for the Red-leaf disease, was obtained. The vineyards of these growers are situated respectively in the south, in the north, and in the east of Sonoma County.

Those portions of their vineyards supposed to be most affected with this disease were selected for experimental purposes. It had been our intention to divide the plots off and to spray them after the manner shown in the following diagram, but owing to inclement weather the spraying with the iron sulfate was not completely carried out, except at the East Sonoma experiment plot.

1. Arrangement of Experiment Plots.

1	2	3	4	5	6	7	8	9	10	11	12
Iron sulfate,	Witness,	Iron sulfate, Bordeaux mixture,	Witness,	Bordeaux mixture,	Witness,	Iron sulfate,	Witness,	Iron sulfate, Bordeaux mixture,	Witness,	Bordeaux mixture,	Witness,

The *North Sonoma experiment plot* was not sprayed with the iron sulfate at all, and the diagram of the plot as sprayed would be:

Bordeaux mixture
Witness
Bordeaux mixture
Witness
Bordeaux mixture

The sprays used,* the dates of their application, the amount of each used per acre, and the length of the vine shoots when they were applied, are given in the following tables. From these tables the cost of the spraying, exclusive of the labor, may be approximately determined:

Amount of spray used on fair vines of the Burger variety; 1210 vines per acre.

Date.	Acid Iron Sulfate.	Bordeaux Mixture.	Average Length of Canes.
May 3 and 4	Was unable to	70 gallons	9 inches
May 23	use this spray	85 gallons	30 inches
June 7	on account of	100 gallons	36 inches
July 19	bad weather.	140 gallons	3.5–4 feet

On the *South Sonoma experiment plot* half of the intended spraying with the iron sulfate was carried out.

Amount of spray used on old, large vines of the Mission variety; 680 vines per acre.

Date.	Acid Iron Sulfate.	Bordeaux Mixture.	Average Length of Cane.
February 2	400 gallons	none	0
April 28	none	80 gallons	9 inches
May 13	none	105 gallons	20 inches
June 14 and 15	none	270 gallons	3.5–5 feet
July 18	none	530 gallons	4–6 feet

The growth of the vines at the *East Sonoma experiment plot* was too uneven to be of value for tabulation.

The three experiment plots very soon proved to be of very unequal value for the study of the Red-leaf disease. The vines in the East Sonoma plot were practically not affected by this disease, though seriously menaced by one which will be described below under the name of Grape-shrivel. The Red-leaf disease was prevalent in the North Sonoma plot, but so also was the Root-rot. At the South Sonoma plot, however, the vines were not affected with any other disease than the Red-leaf, and it is there that practically all the data on the development and progress of this malady were gathered. Notwithstanding the presence

*The sprays used were: 1.25 per cent Bordeaux mixture, and acid iron sulfate. The acid iron sulfate is prepared as follows: Ten pounds of iron sulfate are placed in a half-barrel, one pound of commercial sulfuric acid is poured into the copperas (to prevent sputtering, which is objectionable, the acid *should always* be added before the water), then 12.5 gallons of water are added and the mass stirred until the sulfate has dissolved. In making large quantities of the acid iron sulfate spray it is more expeditious to use hot water. The iron sulfate is only a winter spray, and can not be used after the buds have swollen.

of other diseases, the North Sonoma plot, and a few side excursions to other vineyards, were, however, of valuable assistance as soon as some knowledge of the characteristics of the Red-leaf disease had been obtained. By their aid the limits of variability of these characteristics were established with considerable accuracy.

In the following discussion of the effect of our spraying experiments in controlling the Red-leaf disease, together with the observations on its progress and development in the vineyard, the data collected at the South Sonoma experiment plot form the basis of our discussion.

Details of the Work at the South Sonoma Experiment Plot.—The plot was established among old Mission vines which had been more or less

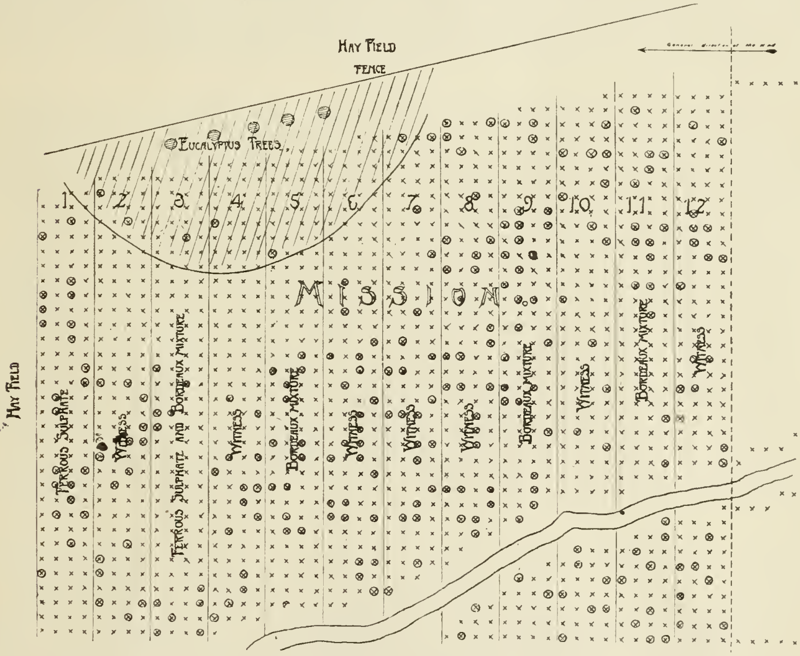

Fig. 1. Map of South Sonoma Experiment Plot.

diseased in 1902 and 1903 and were beginning to cause some concern. By referring to the map (Fig. 1) the reader will at once see the manner in which the plot was laid off and sprayed. The times at which the sprayings were given have already been mentioned. The interval between the sprayings with the Bordeaux mixture was so timed as to always keep the leaves well covered with a film of the fungicide. The Bordeaux was observed to cause a certain amount of burning in the young leaves, especially in the earlier part of the season. This burning of the tissues, which occurs between the veins and in stripes, the leaves becoming, as a consequence, somewhat crinkled and distorted, should not be confused with the characteristics of the Red-leaf disease. The

vines sprayed with the acid iron sulfate were greener than the witnesses, at least during the first part of the growing season; the vines sprayed with the Bordeaux mixture were much greener than the witnesses, even in the height of summer. This improvement in the color of the foliage, where and whenever the above fungicides are used, occurs regardless of the presence or absence of disease.

The Red-leaf disease first appeared in the plot on the 10th of June, when a single vine was found somewhat affected. On the 10th of July there was hardly more than one per cent of the vines affected. From then to the end of the season, however, the disease rapidly increased. On the 25th of August about ten per cent of the vines were affected, which gives an increase of nine per cent in thirty-six days. From the 25th of August to the 13th of October, the increase was only five per cent.

If, instead of considering the plots as a whole, we compare the percentages of diseased vines among the sprayed and unsprayed rows, we will find that the Red-leaf disease develops almost as freely in the one case as in the other, with one exception. In the case of the witnesses (average of seven sections) the disease is more rapid from the 10th to the 28th of July than in the case of the sprayed vines; but between July 28th and August 25th it is proportionately less rapid than among the vines sprayed with the acid iron sulfate and not much greater than among those sprayed with the Bordeaux mixture. The rapid rise in the percentage of diseased vines in the sprayed rows begins later than in the average of the witnesses, and on the 28th of July. On the 12th of August the vines sprayed with the iron sulfate show a greater percentage of diseased vines than the witnesses, and throughout the remainder of the season continue to do so. Among the vines sprayed with the Bordeaux mixture the percentage of disease remains below that of the witnesses, except on the 13th of October, when it is almost one per cent higher. The vines sprayed with the iron sulfate and Bordeaux mixture (one section) showed 1.6 per cent diseased vines all through July; between July 28th and August 12th the percentage increased to 5.4 per cent, and from that date until October 13th the number of diseased vines gradually increased until it reached 9.3 per cent. (See Fig. 2.)

The distribution of the diseased vines in the plot is quite sporadic. The disease does not progress from any one center, or many centers.

In the map (Fig. 1) the position of the diseased vines on October 13th is marked by a circle; the crosses representing the vines. The reader will at once notice that the diseased vines are very scattered, their grouping very indefinite, and he would be unable to tell from the map where the disease first started. On the 10th of June there was one diseased vine in sections 6, 8, 12. On the map, which shows the position of the diseased vines on October 13th, there is not the remotest suggestion of four centers of infection. From this fact we may conclude that priority of infection has little to do with the spread of the Red-leaf disease. And this is the more especially worthy of note since priority of infection is generally a most decided factor in the spread of parasitic diseases. The reader has only to recall to mind the action of the Phylloxera, the Root-rot, the Mildew, etc. The parasite causing a given disease may spread from one plant to another in a more or less regular

manner, which depends largely on the nature of the parasite and the surrounding conditions. If the parasite lives on the roots of the plant, it will spread, as it were, in a circle; but if it is a leaf parasite, the wind, all other things being equal, will cause the disease to spread with greater rapidity in the direction in which it blows. Furthermore, when a plant is preyed upon by some parasite, it shows all the symptoms characteristic of the specific disease, from the minor to the major in sequence.

Now if we apply these principles to the study of the Red-leaf disease,

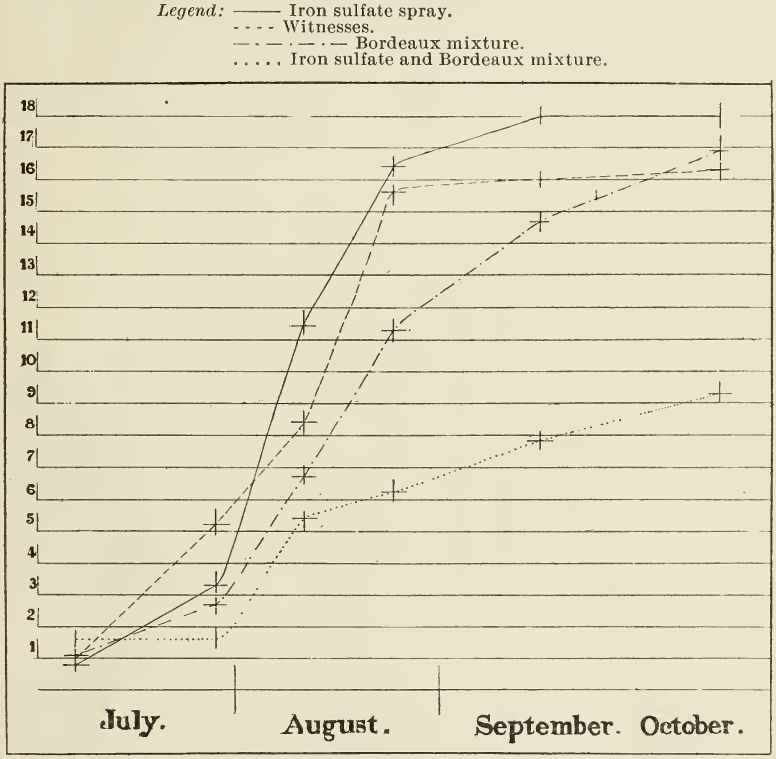

FIG. 2. Progress of the Red-leaf disease (in per cent) on the South Sonoma Experiment Plot.

we find that it does not spread from a center of infection. A vine is often diseased on a single shoot; it may show the first symptoms of disease in the early summer, and never at any other time. Some healthy vines may in seven days be affected in the worst form, while others have only a cane or two, or even only the apical leaves of a few shoots, affected. These observations tend to show that the Red-leaf disease is not caused by a root parasite.

It remains to be seen whether or not the Red-leaf disease can be caused by a leaf parasite. The disease progressed, the reader will remember, from section 2 toward section 12 (Fig. 1). This progression was still

quite noticeable in July. The interesting feature of this progression is the fact that it was contrary to the direction of the wind, which blew daily across the plot in the direction shown by the arrow. The wind blew from right to left; the disease progressed from left to right; a leaf parasite would, other things being equal, follow the direction of the prevailing wind. Furthermore, the vines were, in at least seven tenths of the cases, more diseased to windward, notwithstanding the Red-leaf disease progressed against the wind. Again, the vines that were somewhat weakened by their proximity to the eucalypti (see shaded part of map) and were shaded by them in the afternoon, were barely touched by the Red-leaf disease, and that only after the terrific hot weather in September.* The leaves of these vines were thinner and less consistent than those of the vines in constant sunlight. They were decidedly wanting in vigor, and yet remained practically untouched by the disease.

It seems difficult to reconcile the above facts with the development of a leaf parasite. We are more inclined to believe that the Red-leaf disease is due to the same causes as the Folletage and the Rougeot, namely, a disturbance of the equilibrium between the absorption of water by the roots and its transpiration by the leaves.

The soil in which the vineyard is planted is a clay loam underlaid, at a depth of from three to four feet, by an impermeable clay subsoil, at the left of the plot; in the middle, however, the soil is deeper and the subsoil more permeable; toward the right the soil becomes deeper still and more gravelly as one goes down. At the end of July there was from 2 to 3 per cent of free moisture in the soil, which is enough, as the vines showed, to support a good growth and crop of fruit, but which might easily become inadequate to supply the demands of the leaves in moments of great transpiration activity.

Wind, as is well known, activates transpiration considerably and, under such conditions, might well become the inciting cause. If we take into consideration that the vines were more affected with the Red-leaf disease to windward, and that the disease progressed, in the early part of the season at least, from that part of the plot underlaid by the impermeable clay to that with the freer subsoil, we have two facts which bear out our hypothesis very well.

This hypothesis, however, has against it the results shown by section 3, which was sprayed with the iron sulfate and the Bordeaux mixture. In this section, at the end of the season, there was not more than ten per cent of the vines diseased, whereas in the other sections the percentage of diseased vines was almost double. From the production of the vines in the different sections, we are unable to gather any evidence for or against our hypothesis. (See Fig. 3.)

*This hot weather occurred on the 6th, 7th, and 8th of September, when the thermometer stood at 90° and 105° F. in the shade.

In regard to the effect of soil fertility on the Red-leaf disease, some evidence well worthy of experimental control was obtained. In September, 1903, in a cursory examination of the vineyard in which the experiment plot is situated, it was noted that the foliage in a "block" of old Mission vines which were much larger and at least ten years older than those in the experiment plot, showed very generally the discoloration of the Red-leaf disease. These old Missions were given a good dressing of stable manure during the winter of 1903. In 1904 they were kept more or less under constant observation. On September 16th of that year we noted that the old Missions, which the previous year showed the foliar characters of the Red-leaf disease so markedly, were still healthy.

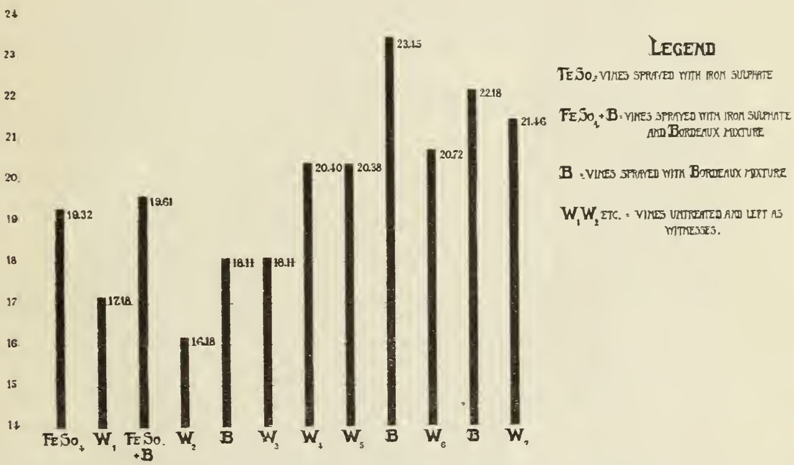

FIG. 3. Table showing the average production (in pounds) of the vines, both sprayed and unsprayed, at the South Sonoma Experiment Plot.

From these observations one would surmise that fertilizing, with stable manure at least, would have a certain action in controlling the Red-leaf disease. If, moreover, coupled with these observations, it were found that the soil was at all deficient in one or all of the plant foods, then our surmise would become a plausibility, if not a certainty. We had, therefore, the soil (an average sample) of our experiment plot analyzed, and with the following result: The soil was found to contain less than 0.05 per cent of phosphoric acid, which is quite low for a productive soil. When we couple with this deficiency of phosphoric acid the fact that the grapevine consumes more of this nutrient than most fruit trees, it is not rash to assume that fertilization will greatly help the vines to at least withstand the Red-leaf disease.

THE GRAPE-SHRIVEL.

The disease that we have denominated the Grape-shrivel is not as yet, at least so far as known, of any great economic importance; but, owing to the circumstances under which it occurs, it is highly probable that it exists elsewhere in the reconstructed vineyards of California and may, therefore, assume, at any moment, more than local interest. The fact that we observed the Grape-shrivel in the East Sonoma experiment plot, where it took the place of the Red-leaf disease, is suggestive enough, even though it was not observed at either of the other experiment plots, or in vineyards visited.

Description of the Grape-Shrivel.—The Grape-shrivel, as its name implies, is characterized by the shriveling of the berries. In fact, this shriveling is the only diagnostic character of this disease, the symptoms which appear in the leaves being easily referable to drought, or imperfect nutrition.

The Grape-shrivel develops quite rapidly, as shown by the fact that while no symptoms of the disease were observed on the 27th of June, yet on the 12th of July many vines were affected. By the end of July practically every vine in the experiment plot showed the characteristic shriveled grapes of this disease.

The distribution of the Grape-shrivel is at first somewhat irregular, then general. The grapes on weak vines (not necessarily dying vines) and strong vines are equally affected. The fruit on weak shoots and strong shoots is affected alike. The general health of the vine seems to bear no relation whatever to the distribution and intensity of the disease. Vigorous, weakly and dying vines (all with affected grapes) commingle; there are not the usual regular, or semi-regular, depressed areas of vegetation so characteristic of parasitic diseases.

Effect of the Disease on the Grapes.—The Grape-shrivel, as already mentioned, is characterized by its effect upon the fruit. The berries* lose their clear, turgid appearance and become dull and flabby (but never blotched, as in the Red-leaf disease), irregularly wrinkled and, as it were, thick-skinned; as the drying progresses the wrinkling becomes more pronounced and assumes a direction more nearly parallel to the axis of the berry (Fig. 4). When completely dry the berries are uniformly bluish, in some cases, where exposed to the sun, washed with red; they are tightly shrunken around the seeds, and coriaceous. At this stage the pedicels and the peduncle, to within a short distance of the cane, are dried and discolored; the green and dried portions of the peduncle become severed, and the completely desiccated bunch of

*As we have only observed the Grape-shrivel on one variety of white grape (the Semillon) the description of the effect of the disease on the berries can only apply integrally to varieties of the grapevine producing white fruit.

grapes falls to the ground. Such is the progression of the disease in the grapes while they are still green, but, when they begin to mature, the shrinkage becomes less total as the absolute percentage of sugar increases in the fruit.

The fruit of diseased vines, when it does not shrivel, often ripens prematurely. This prematurely ripened fruit is frequently edible, though sometimes quite distasteful.

The manner in which the malady works on the different bunches of the same cane is quite characteristic. The lower bunch of grapes is the

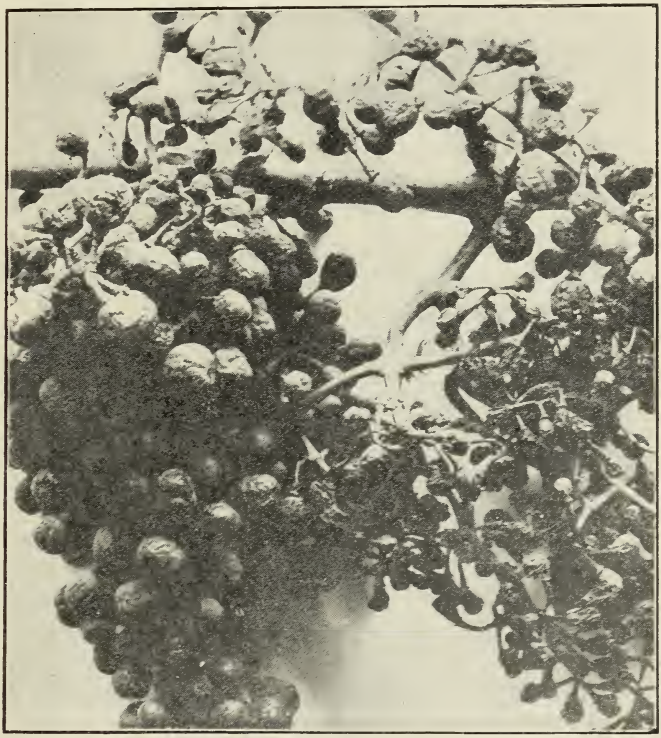

FIG. 4. Bunches of grapes showing progress of Grape-shrivel.

first to show signs of the disease; it is not rare for one to find the lowest bunch much diseased, and the upper just beginning to show the first signs. We have even found, on canes bearing three bunches of grapes, the first bunch completely desiccated, the second shriveled, and the third absolutely sound. There are canes, however, in which the differences are less marked, and some even in which the progression of the disease is reversed.

Effect of the Disease on the Leaves.—The disease does not show in the foliage at first. The leaves of strong, healthy vines and strong, healthy shoots remain turgid and green; the leaves of weaker vines and weaker

shoots may be somewhat faded and yellow. The yellow coloration may be total or partial, and the leaves irregularly dry in those parts of the parenchyma longest deprived of chlorophyll, that is from the edges inward. The lower leaves are more affected than the upper.

Following the shriveling of the grapes, the foliage of the more vigorous vines, after a longer or shorter time, begins to show the same characters that the leaves of the weaker vines assume at an earlier period. These characteristics are illustrated in the accompanying colored figures on Plate I. The chlorophyll becomes resorbed at the edge of the leaf (Plate I, Fig. 7), which yellows; this resorption may continue until the whole of the leaf is bright yellow (Plate I, Fig. 1). Following this stage, which is not infrequent in the basal leaves, the leaf either dries up completely and at once (Plate I, Fig. 3), or, as occurs more often, from the periphery inward, with a slight rolling of the edges (Plate I, Fig. 2). In other cases, however, the entire blade of the leaf does not become so regularly yellow and then dry. Indeed, one frequently observes the yellowing at first confined to the apical lobe (Plate I, Fig. 4), and then gradually progressing toward the petiole (Plate I, Fig. 5), the wings of the leaf remaining the while of a sub-healthy green. The chlorotic tissue gradually dries, sometimes irregularly, but not infrequently in a very regular manner (Plate I, Fig. 6). As soon as the center portion of the leaf has dried, the wings of the leaf die. Fig. 6 represents a leaf, the center of which became chlorotic and then dried up; the death of the entire leaf then followed.

A leaf presenting the characters of that illustrated in Fig. 8 is more exceptional. In this leaf the greater part of the leaf-blade was suddenly killed without previous yellowing or chlorophyll resorption. The dead tissue, it will be observed, has a shade of green in it, whereas in all the other diseased leaves it is fawn-colored or brown. If the reader will imagine the dead tissue (Fig. 8) colored brown instead of greenish-fawn, he will have the representative of a leaf that was chlorotic around the edges and in the greater part of the blade. This chlorosis, however, did not spread, and the affected tissue rapidly died without impairing the functions of the remaining healthy portion of the leaf.

Internal Appearance of the Shoots, Spurs, Arms, and Body of Vines.—The spurs, the arms, and the body of the vine show no outward signs of disease at all. The shoots mature sometimes very unevenly, but this characteristic is unimportant. The shoots, spurs, and body of the vine show, however, certain internal symptoms which should be noted.

Cross and longitudinal sections of the shoots, spurs, arms, and body of the vine show discolorations in the wood and pith. In the shoots a slight discoloration of the woody tissue next the pith can be traced with comparative ease at least as far as the last bunch of grapes showing shriveling; but the brown discolorations in the pith are not so constant:


1
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now and then they may occur just above and below the diaphragms, and without regularity; at other times a slight discoloration of the pith may be traced from the base of the shoot up several nodes. In the spurs the woody tissue of the previous year is brown and often, more especially near the edge, zoned with darker lines. In the arms we have the same general appearance as in the spurs, with this difference that, in cross-section, the darker areas may be more suffused. In the trunk the discolorations of the wood are less pronounced and, in longitudinal section, appear as striations which become less numerous as one nears the stock (the diseased vines are grafted on Lenoir), which they rarely penetrate to any extent; or, if no decay or dead tissue is present, the live wood may be suffused with a faint brown tinge, from which the striations stand out less boldly. The bodies of the vines have, however, in most cases suffered more extended disorganization than just described. One finds, whenever large limbs have been at one time removed, decay and dead tissues occupying a large part of the body of the vine and eating gradually down toward the stock, which is rarely affected, however, to any serious extent.

The roots are always healthy, even in sickly vines.

Generalities regarding the Work at the East Sonoma Experiment Plot.—This plot was established in a vineyard reconstituted some twenty years ago. Lenoir was the grafting stock originally used; but from time to time, as vacancies occurred, other stocks—mostly Rupestris of the Fort Worth type—were used to fill in the missing places. In that part of the vineyard selected for the experiment plot (the only really diseased portion) the Lenoirs are carrying Semillon grafts.

The plot, however, is not free from admixture. A few Zinfandels are scattered here and there and were evidently accidentally introduced when refilling the vacancies. When the vineyard was reconstituted the grafting was well done and the grafts were not allowed to strike root. Furthermore, there was never any great disparity of growth between the stock and graft, and consequently the unions are smooth. The vines were pruned short prior to 1902, and, in consequence, had never produced much of a crop, the Semillon being one of the grapes that demands long pruning to produce fully. The vines, however, under, this régime, were moderately healthy and sufficiently vigorous. In 1902 the system of pruning was changed from short to long. Following the adoption of the long pruning the vines began to show disease. In 1903 they were already much affected. This new disease was then supposed to be the Red-leaf disease. We now know that it was the Grape-shrivel.

Acting on the assumption that the disease in this vineyard was the Red-leaf, arrangements were made in February, 1904, to carry out there the same spraying experiments as at the other two plots. The East Sonoma plot was divided into twelve sections, containing four rows of vines each. Sections 1 and 7 were sprayed with acid iron sulfate,* sections 3 and 9 with acid iron sulfate and Bordeaux mixture; sections 2, 4, 6, and 12 were left as witnesses. Sections 1, 3, 7, and 9 were

*For the method of preparing this fungicide, see page 12.

sprayed with the acid iron sulfate on the 28th of March, just as the buds were beginning to swell. Sections 3, 5, 9, and 11 were sprayed with Bordeaux mixture (4 pounds of copper sulfate, 4 pounds of lime, 40 gallons of water) on the 6th and 26th of May, and the 16th of June.

The growth of the vines on the sprayed and unsprayed rows was sporadic and uneven. After the second spraying with Bordeaux mixture the foliage of the sprayed vines was somewhat greener than that of the witnesses. By the 16th of June, the date of the third spraying with the Bordeaux mixture, no specific signs of disease had shown in either the witnesses or the treated vines, other than such as might be referred to known causes. The appearance of the plot was in no way such as to create a fear that the vines would collapse and fail to ripen their fruit. On the 27th of June the general appearance of the vines was somewhat wan, and the line of demarkation between the sprayed and unsprayed vines had well-nigh ceased to exist. On the 12th of July, however, almost every vine in the plot showed unmistakable signs of suffering; the foliage was pale, and many clusters of grapes had already shriveled, or were just beginning to collapse; there was no longer any difference between the witnesses and the sprayed vines. In fact, so general were the symptoms of disease in both the treated and untreated vines that any further attempt to check it with Bordeaux mixture was given up as useless. By the end of July practically every vine in the experiment plot was affected with the Grape-shrivel, with the exception of the Zinfandels and the non-grafted Lenoirs.

On the 21st of July, when well-nigh every vine in the plot was affected with the Grape-shrivel, the free moisture in the soil, a loam underlaid at the depth of two feet with a gravelly clay-subsoil, varied between nine and ten per cent.

The roots of the stock in different parts of the plot were examined from time to time for the purpose of determining their resistance to the Phylloxera. Nodosities were always found to be present in plenty, both on the grafted and on the non-grafted Lenoirs.

At the end of July one per cent of the vines in the experiment plot were dug up, split open and examined. The result of this examination is given on page 20, where the internal appearance of the shoots, spurs, and body of vines affected with the Grape-shrivel is described.

In the beginning of August a critical examination was made of the vines in the plot, for the purpose of determining if there was any relation between the vigor of the vine or of any of its individual shoots, and the Grape-shrivel. The only fact this examination clearly revealed was that the vines had been given too liberal a pruning. In general, no more than half the eyes left at pruning time had sprouted, and sometimes less.

The yield of the experiment plot (one acre) was about 700 pounds of

grapes. The Grape-shrivel had destroyed the four or five tons of fruit that the showing of the vines in June would have led one to expect.

Cause of the Grape-shrivel.—From the description of the Grape-shrivel, and the manner and circumstances under which it develops, it is evident that the disease is a peculiar manifestation of imperfect nutrition. The yellowing and dying of the leaves, beginning at the base of the shoots, is characteristic of vines suffering from want of water. Premature ripening is also a consequence of lack of water. The fact that the grapes shrivel, often previously to the discoloration and wilting of the foliage, does not invalidate this contention; for, it may be shown that under the influence of drought, or a paucity of free water in the soil, the fruit of the French prune will shrivel even when the foliage is healthy and luxuriant. It is, therefore, no stretch of the imagination to suppose that the same phenomenon happens in the case of the vine. In fact, in several cases we have obtained experimentally the characteristics of the Grape-shrivel as shown in the grapes. Our experiments, though crude enough, were quite instructive. We severed, in healthy vines, several long canes bearing vigorous shoots carrying well-developed bunches of grapes. Almost immediately after the canes were severed the shoots began to wilt, as one would expect. The bunches of grapes, however, generally wilted as they do in the case of the Grape-shrivel: the lower bunches on a shoot would frequently dry out faster than the others. We also observed that the pith discolored in the neighborhood of the diaphragms first, and that the wood tissue became discolored.

The discoloration of the pith in the shoots, and the discolorations in the spurs, arms, and trunk, may be shown to occur in vines under very varied and divers circumstances, and are, therefore, at most of but secondary importance.

The symptoms of the Grape-shrivel, then, are those of a vine suffering from drought. This is further emphasized by the following facts:

The Lenoir, the stock upon which the Semillons are grafted, is not very resistant to the Phylloxera. Its rootlets (which, the reader will bear in mind, are the active agents in the absorption of water) were much distorted by the Phylloxera, and their functions, therefore, interfered with. This fact explains how it is that a vine grafted on Lenoir (or any other stock sensitive to the Phylloxera) could suffer from want of water, even when the soil contained nine or ten per cent of free moisture. But it may be asked, why does the non-grafted Lenoir not suffer? This question is easily answered. The Lenoir is not as vigorous a grower nor as heavy a bearer as the Semillon. When it bears the Semillon, then, or any other vinifera more vigorous than itself, its rootlets, even when not preyed upon by the Phylloxera, are unable to take up and transfer to the graft its optimum of food; and the bigger

and finer the graft the greater the difficulty the Lenoir has in supplying it with its full quota of nutriment.

But if the rootlets of the Lenoir are much damaged by the Phylloxera, the equilibrium can not be maintained and the graft will show signs of distress. Why, then, have the vines at the East Sonoma experiment plot lived so long? The answer to this question is, that the vines were formerly short-pruned and were unproductive, but that since 1902 they have been long-pruned and made to produce largely.

In the first case the equilibrium between the stock and the graft was practically maintained; in the latter, it was destroyed. It must not be forgotten, however, that the Phylloxera is in a measure an active agent in causing the Grape-shrivel, and that the severity of the disease during 1903 and 1904 may be due to circumstances favoring the development of this pest.

In combatting the Grape-shrivel on grafted vines, two things must be taken into account: First, the affinity between the stock and the graft; second, the resistance of the stock to the Phylloxera.

The affinity (and by affinity we mean all the necessaries to a conjoint life) between stock and scion is to be maintained in equilibrium by judicious pruning, supplemented by thorough fertilization.

The resistance of the stock to the Phylloxera will be indirectly heightened by fertilization; but if then found to be insufficient, it should be changed for a more resistant one. The use of bisulfid of carbon, in protecting stocks of low resistance from the attacks of Phylloxera, is not at present an economic possibility.

ROOT-ROT.*

The action of this disease in its main characteristics is very similar to the malady known among the French as the Pourridié, or Blanc des racines, and in Germany, according to Mr. P. Viala,† by the name of Weinstock-fäule. The areas of depressed vegetation that one associates familiarly with the action of the Phylloxera, are characteristic also of the Root-rot. In each case there is a center of infection, though, when compared with the Phylloxera, the Root-rot spreads more slowly and appears circumscribed or local in its action. In the case of the Root-rot there may occur many small centers of infection in close proximity to one another which may take several years to merge into one; whereas, in the case of the Phylloxera, when infection is so general that several centers start very near one another, they rapidly become one.

* These remarks of Mr. Butler on the Root-rot are of very great importance at the present time, as this disease is doing a great deal of damage in certain parts of Santa Clara, Sacramento, and San Joaquin valleys. In some districts the Root-rot is far more destructive than the Phylloxera. (E. H. T.)

† P. Viala: "Les Maladies de la Vigne," 3d ed., page 248.

The Root-rot is caused by a fungus,—possibly several fungi,—and in its usual form is very easily recognized upon digging up any vine within an infected area. The roots are soft, watery, yellowish-brown in the entire woody cylinder, and more or less permeated with whitish threads—the mycelium of the parasite—and give off a strong nauseous fungous odor. As the lower roots are destroyed, and the mortification enters the body of the vine and slowly eats its way in the trunk to the surface of the soil, and even above, new roots are sent out from the still healthy encompassing tissue; these roots, in turn, become riddled with, and succumb to the attacks of the fungus. In the last stages of the disease (that is, when the vine has sent out a few feeble canes about a foot long) one invariably finds near or at the surface of the soil, a very free growth of young tender roots.

Though the Root-rot is generally of the form just described, and takes from two to five years to kill the vine, it may, in some rare cases and in young vineyards, spread with such rapidity that it kills the vines in eighteen months, and even in a single season. Mr. P. Viala observes: "The vines may succumb in from fifteen to eighteen months," and that he "has even caused their death in six months by placing them under the most favorable conditions for the development of the Pourridié."*

The author observed, during the summer of 1904, in a young vineyard, a remarkably intense and destructive attack of Root-rot, which, in many instances, had gained an entrance into the vines during the late spring or early summer, and had practically ruined the greater part of them by October. Many there were that would not "come out" in the spring, or, if they did, would die during the summer.

The growth of vines affected with the usual form of Root-rot resembles that of vines affected with the Phylloxera. Their growth gradually becomes weaker and weaker, and the vines finally die. But in the *rapid form* of this disease there is no such gradual wasting away. The foliage of the vines becomes chlorotic, and, if the weather is at all unfavorable, rapidly sears and falls off. The blade of the leaf not infrequently separates from the petiole, which remains a while longer attached to the shoots. The maturity of the shoots is impeded; their lignification is imperfect, irregular, and at times resembles that which has come to be considered typical of the Anaheim disease; in other words, strips on elongate spots of immature tissue may be found in the midst of mature wood. The fruit matures imperfectly. The photograph of the vine shown in Fig. 5 was taken early in October, and shows the general appearance of a young vine affected with the rapid form of the Root-rot. The vine was evidently not affected with this disease, if we may judge from its growth, until late in spring.

The appearance of the diseased vines below ground is necessarily different from that of those affected with the milder form of the Root-

*P. Viala: "Monographie du Pourridié," Introduction.

rot. Instead of the entire underground portions being soft, watery, and decayed, the woody cylinder suffers no outward disorganization, but is more or less discolored according as it is examined nearer to or farther from the original center of infection. In fact, so slight is the

Fig. 5. Young vine killed by Root-rot.

decay of the tissues that a vine, when cursorily examined after it has been dug out, shows no signs of a specific disease. The bark on the stem is tight and dry, and is not suggestive; on the roots it is often streaked with filmy white, but even this is not characteristic enough to hold

one's attention. But when one examines a diseased vine a little more closely he discovers that it gives off the nauseous fungous odor so characteristic of the Root-rot, and that a cross-section through the stem or roots shows, between the wood and the bark, a dirty white subcontinuous line, which is not very distinct and is easily overlooked. If, however, a piece of the bark is cut off, there will appear between it and the woody cylinder a white, or grayish felt-like, mass of interwoven threads—the mycelium of the Root-rot fungus. The vine shown in Fig. 5 was one mass of this fungous growth to within an inch or so of the surface of the soil.

The vineyard in which the exceptionally severe form of Root-rot just described was observed had been established in 1902, on land that had been cleared during the year 1900. The piece of land on which the vineyard is planted lies on the sunny slope of a fairly steep range of hills. This slope in profile might be likened to an S reversed and considerably drawn out lengthwise, and lying at an angle of about thirty degrees with the horizontal. The soils in this piece of land are both poor and good. Beginning at the bottom, and extending up the slope some one hundred feet, we find a very shallow sandy soil, inclined to be compact and hard, and underlaid, at a depth of a foot or more, with a clayey subsoil. This soil becomes very wet in winter. On the remainder of the slope the soil is friable, inclined to red, fertile, and with the subsoil considerably below the surface. In this soil the vines may be completely dug out with a spade, whereas a mattock, and a good one, is needed to remove the vines from the soil at the bottom of the hill. The growth of oaks, before the land was cleared, was meager at the bottom of the slope, on the refractory soil, but quite dense everywhere else. A year after the land was cleared the vines were planted. They were Carignanes grafted on resistant stocks. On the light, friable soil the Rupestris St. George was the stock employed; whereas on the refractory soil at the bottom of the hill, Rupestris of the Fort Worth type appears to have been exclusively used. The former were more vigorous than the latter.

These being the facts one would naturally expect the Root-rot to develop first among the Fort Worth Rupestris, and spread from these to the Rupestris St. George. This would certainly have been more in accord with the general behavior of Root-rot fungi. The reverse was true, however; the Rupestris St. George and not the Fort Worth Rupestris were the vines affected.

But with the Root-rots, like with many other parasites of both the vegetable and animal kingdoms, the usual areas of adaptability, when one or more conditions are particularly favorable, may be passed over. In fact, it is well known that in the case of the Root-rot, though usually serious only in *wet* soils, it may spread in comparatively dry

soils if the plants growing in said soils happen to be sensitive to the disease, and climatic conditions—a wet winter, for instance—are favorable.

In the case of the rapid form of the Root-rot affecting the young vineyard above mentioned, we know that the land was full of decaying roots and other débris from the oaks that had been grubbed out; we also know that Rupestris St. George is very sensitive to this disease, and, furthermore, that the latter part of last winter was wetter than usual.

The intensive and rapid growth of the Root-rot in a three-year-old vineyard grafted on Rupestris St. George, and established in a soil which, from its situation and friability, would be considered unfavorable to the development of the parasite, is beyond a doubt exceptional. However, this particular case has been dwelt upon, less on account of its economic importance than for the fact that it demonstrates very conclusively the sensitiveness of the Rupestris St. George to Root-rot, a point which we shall have occasion to dwell upon again.

Vines affected with the rapid form of the Root-rot can not, of course, be saved. Vines affected with the usual form are, when treated before the disease has made much progress, amenable to treatment. The preventive treatment here recommended applies equally well to both forms of Root-rot.

The remedial or preventive measures used in combatting the Root-rot, or indeed any other disease attacking the subterranean organs of plants, are, at best, but palliatives. As the disease is more general in soils with an impermeable substratum that are quite retentive and miry after heavy rains, adequate drainage is and will always remain the only valuable preventive and curative measure. For excessive humidity is the exciting cause of the disease; it favors fungous development, and the tissues of the roots are soft, gorged with water, and in no condition to resist the attacks of parasites. An author (Mr. P. Viala*) who has studied the Pourridié of the vine and fruit trees with particular care, says: "One must, to prevent the disease from spreading, and to protect one's self against it in new plantations, thoroughly drain the soils in which it exists, and also those that are, through their retentiveness, favorable to its development." "Drainage is an excellent preventive measure," he continues, "and what is more, the only efficacious one." But as drainage is not always economically possible, a few half measures that are at least useful may be mentioned, even if they have not the virtue of an elixir.

As soon as the disease shows in the vineyard, all badly diseased vines (that is, those vines whose scant growth shows that their main root-system is seriously attacked) should be removed and the vines surround-

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* Loc. cit., page 248.

ing them treated with a three per cent solution of blue vitriol* or a seven per cent solution of green vitriol.† This is done by digging with a hoe a small basin around the trunk of the vines and pouring into it a gallon or so of either solution, the quantity being determined by the nature of the soil and the supposed extent of the root-system. If for any reason it is inconvenient to treat the vines with either of the vitriol solutions, a pound of either the bluestone or the copperas may be placed around the trunks and allowed to dissolve in the winter rains; but this method will not be as effective. Before replanting the areas destroyed by the rot, the holes destined to receive the young vines should be partly filled with either blue or green vitriol solution, and then, when the fungicide has soaked away, planted. In soils that are subject to the Root-rot, rooted vines should always be planted, and as shallowly as cultivation will permit. Cuttings should never be used, for they have to be planted deeper than rooted vines, the chances of infection, especially on the cut surface, being thereby increased.

Vineyards that have once been infected with the Root-rot are, unless drained, always subject to it; therefore, it is essential that those parts that have been destroyed by this disease should, when replanted, be treated every two or three years by one of the methods above outlined.

The Root-rot attacks not only the common grapevine (*Vitis vinifera*), but probably also more or less severely the different resistant stocks. The Rupestris St. George is very sensitive to it; but according to Mr. Jallabert,‡ whose demonstration is quite convincing, the Riparia × Rupestris 3306 is almost immune. He planted the latter in a soil infected with the Pourridié and which, even in the dog days, could only be worked to a depth of six inches. "Somewhat below this the clay was saturated, and, lower down, mud."§ In such a soil as this, and despite the Pourridié, the 3306 flourished. We may feel confident, then, that wherever the Root-rot is bad in California, the Riparia × Rupestris 3306 will more than hold its own.

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*J. Dufour in "Chronique Agricole du Canton de Vaud," quoted by G. Foëx, "Cours Complet de Viticulture," 4th ed., page 603.

† J. Bonjour: "Manuel Pratique du Vigneron," page 71.

‡ J. Jallabert: "Resistance du Rupestris du Lot et du Riparia × Rupestris 3306 au Pourridié," Revue de Viticulture, tome XI, page 92.

§ Loc. cit., page 94 et suiv.

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